Pacific Science (1979), vol. 33, no. 1

Humpback Whales in Hawaiian Waters: A Study in Historical Ecology[1]

LOUIS M. HERMAN[2]

ABSTRACT: Several hundred humpback whales, *Megaptera novaeangliae*, assemble each winter to mate and calve in the nearshore waters adjoining the main islands of Hawaii. Their behavior provides a spectacular display for shore observers and passing boaters. Historical evidence suggests that this population of whales invaded its current Hawaiian habitat only within the last 200 years, and was unknown to the Hawaiians of the pre-European discovery era before 1778. Possible mechanisms for the presumptive recent invasion include dispersion from other areas, accelerated by chronic whaling pressure, and long-term changes in locations of major North Pacific watermasses affecting preferred surface temperature characteristics. A number of short-term local changes in preferred sites within the Hawaiian habitat have apparently occurred in the last 125 years in response to shore-based whaling activities during the mid-nineteenth century, disturbances to the marine environment during World War II, and offshore effects of the poststatehood construction boom on Oahu after 1959. The major habitat shift and the various local site alterations were seen as adaptive responses of the whales to changes in important physical or psychological characteristics of their assembly areas.

EACH WINTER, several hundred humpback whales, *Megaptera novaeangliae*, assemble in the near coastal waters and shallow banks adjoining the main islands of Hawaii. These waters serve as a principal breeding and calving habitat for the whales during their annual migration between subpolar and tropical regions of the North Pacific. Formal studies of this population were begun only recently (Herman and Antinoja 1977, Rice 1977, Shallenberger 1976, Wolman and Jurasz 1977), impelled in part by a need for understanding the effects on the whales of the increasing levels of human marine activity within the local habitat. Humpback whales are classified as an endangered species, and protection of the whales and their habitat is essential. This paper reviews evidence on the history of the whales in Hawaiian waters and their prior interactions there with humans, in order to gain a perspective on factors that might affect the local distribution and abundance of the whales. Since no formal historical records of the whales in Hawaiian waters existed until relatively recent times, most of the data derive from inspection of indirect sources, including material from Hawaiian antiquities, written reports from the early European and American settlers and visitors to Hawaii, logs of whaling ships that visited Hawaii during the nineteenth-century whaling era, newspaper accounts of whaling ventures locally and of whale sightings, and various compendia and treatises on Hawaiiana and Hawaiian natural history.

NORTH PACIFIC WHALING

The prohibition on the taking of humpback whales in the North Pacific by member

[1] This is contribution No. 562 from the Hawaii Institute of Marine Biology. Preparation of this paper was aided by a contract from the National Marine Fisheries Service, Marine Mammal Division, Seattle, Washington, and by grant BNS 77-24943 from the National Science Foundation. An earlier version of the paper was read at the Workshop on Humpback Whales in Hawaii, Honolulu, July 1977. Manuscript accepted 1 July 1978.

[2] University of Hawaii, Department of Psychology and Hawaii Institute of Marine Biology, Honolulu, Hawaii 96822.

nations of the International Whaling Commission in 1966 completed the worldwide protection of humpback whales, with the exception of a few killed each year for subsistence use in Greenland, the Lesser Antilles, and the Tongan Islands (Rice 1977). Worldwide, humpback whales have had a long history of exploitation. The most intensive exploitation occurred during this century, and by 1966 world stocks were reduced to only 5 to 10 percent of their former abundance (Chapman 1974, Myers 1975).

In the North Pacific Ocean, whaling for humpbacks was a continuing low-level process for several centuries until the present one. Japanese shore whaling for the species began in the early 1600s (Omura, Maeda, and Miyazaki 1953). Eastern Pacific aboriginal shore whaling may have already been underway by that time (Rice 1977). During the first seven decades of the nineteenth century, some humpbacks were taken by American whalers operating along the coasts of California and Baja California and in the far western Pacific, particularly in the Mariana Islands region (Scammon 1968, Townsend 1935). However, this period of nineteenth-century whaling was focused principally on the sperm whale (*Physeter catodon*) and the bowhead whale (*Balaena mysticetus*), temporarily sparing the humpback. Modern techniques of whaling with explosive harpoons (a Norwegian invention) were first introduced into the North Pacific near the turn of the twentieth century, greatly increasing the vulnerability of humpbacks migrating past the coastal waters of Japan. A few decades later, whalers began venturing into the summer feeding grounds of the humpback along the upper rim of the North Pacific, killing significant numbers of whales. Additional twentieth-century coastal whaling by Canadians and Americans along eastern Pacific shores further eroded the humpback whale population. During the late 1920s and then again during the early 1960s thousands of North Pacific humpbacks were taken (International Whaling Statistics 1942, 1966). Prior to this intensive twentieth-century exploitation, the abundance of the North Pacific stock was probably at least 15,000 animals (Rice 1977). By 1966, there were probably less than 1000 animals remaining (Herman and Antinoja 1977, Rice 1977).

The first estimates and counts of the Hawaiian population have ranged from 250 to almost 600 animals (Herman and Antinoja 1977, Shallenberger 1976, Wolman and Jurasz 1977). Two other North Pacific breeding populations, one on the American side of the Pacific and a second on the Asiatic side, comprise the remaining stock of North Pacific humpback whales, but these stocks may together number only a few hundred animals.

THE HAWAIIAN HABITAT

Figure 1 shows the Hawaiian Archipelago, consisting of the Northwest Hawaiian Islands stretching from Nihoa to Kure Atoll and the eight main Hawaiian Islands spanning from Niihau to Hawaii. The total archipelago spans some 1400 nautical miles. The whales are found almost exclusively within the 100-fathom (183-m) contours surrounding the main islands (Figure 2) and are especially abundant within the four-island region of Molokai, Lanai, Maui, and Kahoolawe (insert), and within the shallow Penguin Bank area extending some 25 nautical miles southwesterly from western Molokai (Herman and Antinoja 1977, Wolman and Jurasz 1977). There is no evidence of current habitation by the whales in the northwest Hawaiian Islands, though a few "strays" may be occasionally encountered there.

Oceanographic characteristics of the main Hawaiian Island region were summarized by Seckel (1962). Between December and April, which is the main period of residency of the whales in Hawaii, surface water temperatures remain between 24° and 25° C. This temperature range seems to characterize humpback whale breeding habitats worldwide (Dawbin 1966, Winn 1977). The temperature gradient north of the islands decreases approximately 0.7° C per degree of latitude. Maximum salinity in the Hawaiian Island region occurs between November and February.

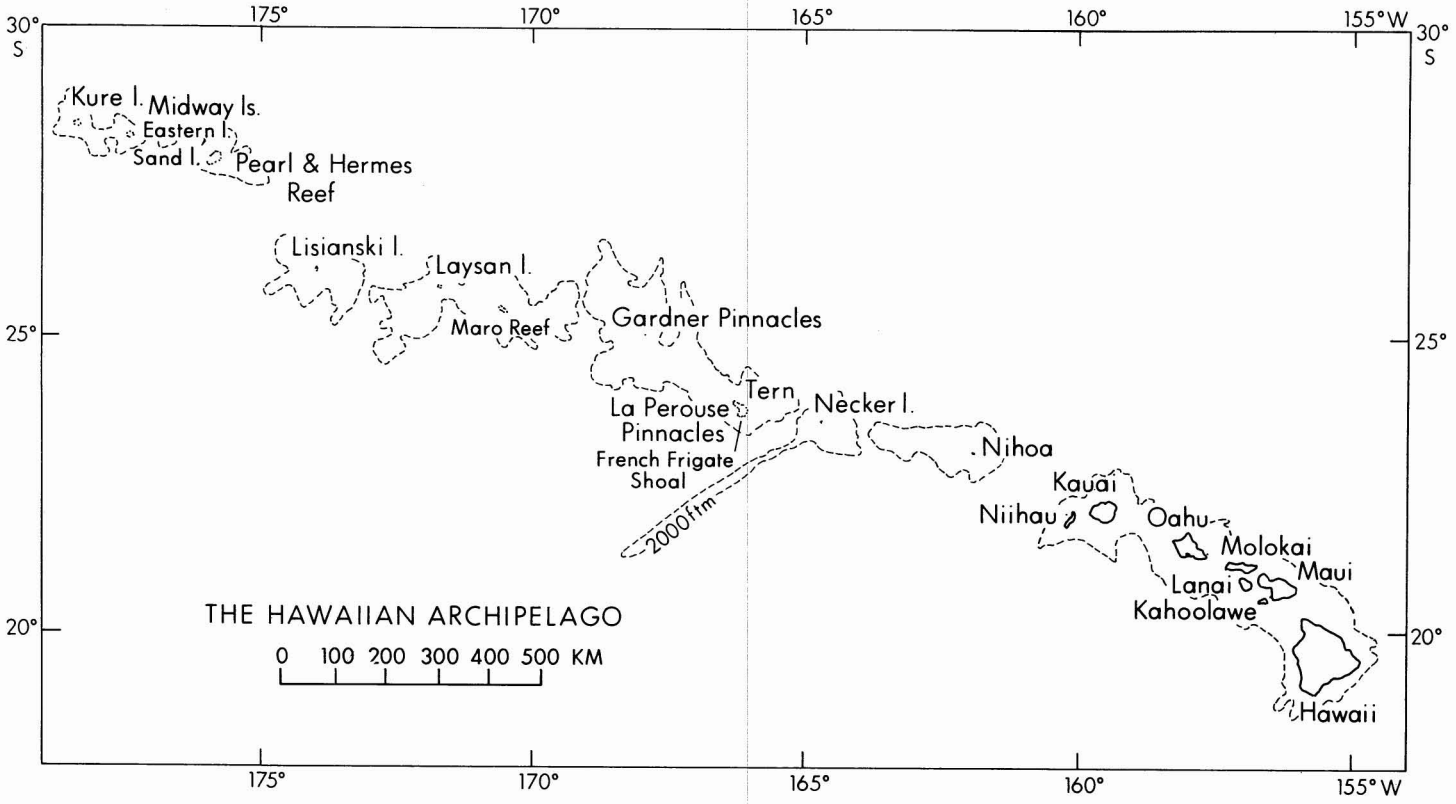

FIGURE 1. The Hawaiian Archipelago from Hawaii to Kure Atoll, showing the 2000-fathom (3600-m) contour.

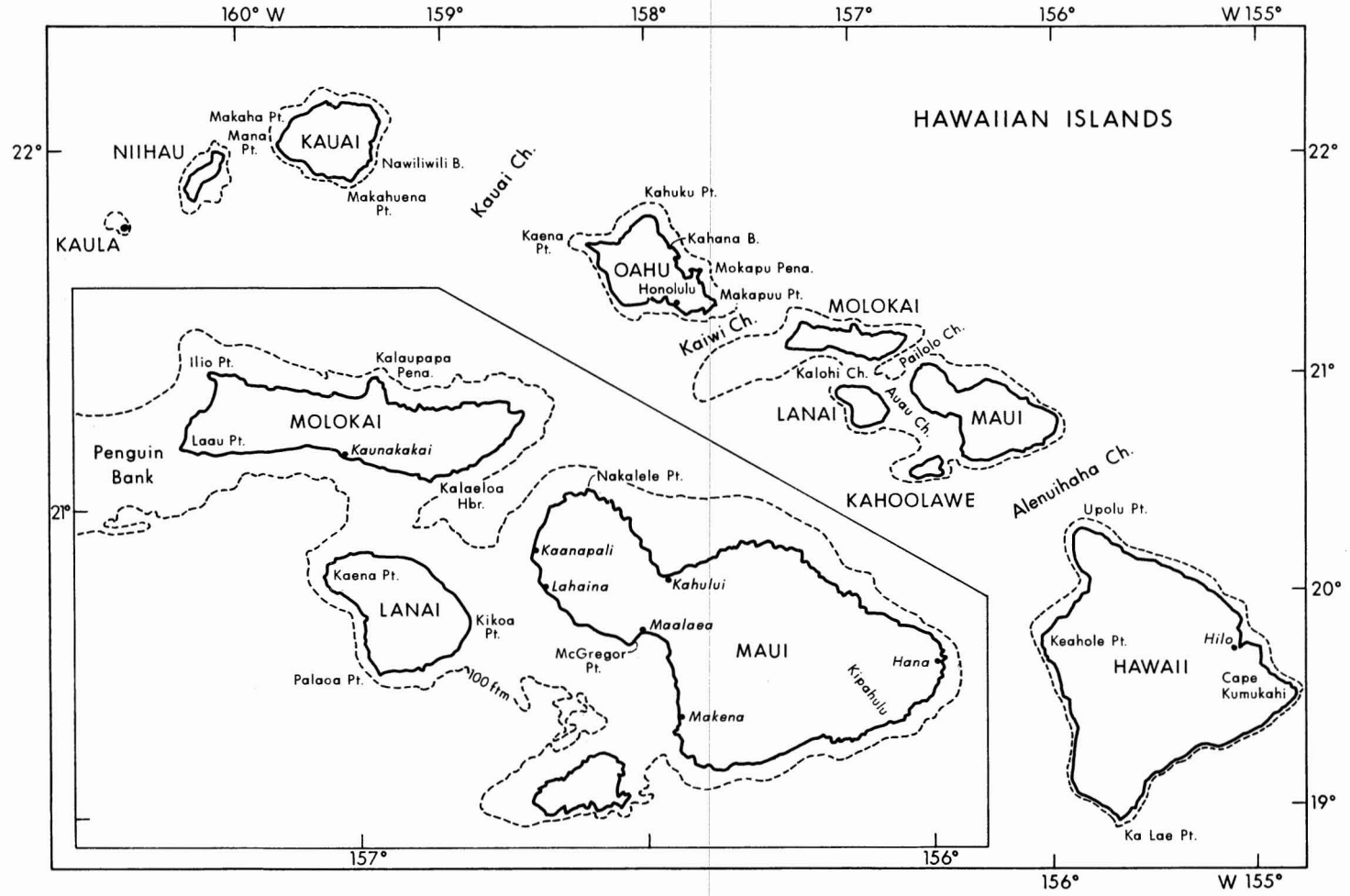

FIGURE 2. The main Hawaiian Islands, showing the 100-fathom (183-m) contour within which almost all the whales are found. The inset expands the four-island region of Molokai, Lanai, Maui, and Kahoolawe, a shallow-water area of dense concentration of whales.

The boundaries of the western North Pacific, eastern North Pacific, and Equatorial Pacific watermasses (large regions of relatively constant temperature–salinity characteristics) meet near the Hawaiian Island region, making the area susceptible to local changes in oceanographic characteristics from time to time (Sverdrup, Johnson, and Fleming 1942). Northeast tradewinds are present from 55 to 65 percent of the time from December through March, producing consistent wave action on the windward coasts. Other winds from the south and occasionally from the north produce the remainder of the wind and swell patterns. There seems to be no consistent relationship between wind or swell patterns and habitation by the whales.

Humpback whales are believed not to feed to any significant degree during their residency in breeding waters (Dawbin 1966). In Hawaii, zooplankton is available, but in significantly lesser concentrations than in equatorial waters or in waters further to the north of the islands (King and Demond 1953, King and Hida 1954). The relatively low zooplankton abundance and the fact that runoffs from land have little permanent effect on the nearshore environment favored by the whales make for clear waters and good observation conditions from shore or boat. Anyone who ventures out in a boat within the four-island region (Figure 2) during February or March will almost surely encounter whales at close hand. At present, during their period of residency in Hawaiian waters, the whales provide a spectacular display that is easily seen from many shore vantage points. The aerial leaps of the whales send up huge sprays of foam visible at great distances, and the sounds of the 40-ton animals landing flat on the surface of the water echo for many miles. A whale may slap its huge tail on the surface a dozen or more times in succession, and these slapping sounds also carry for great distances. Many times, whales mill about a few hundred meters or less from shore, and their blows (exhalations) and other surface activities are easily seen. Their pectoral fins, which are 4 to 5 m long, with bright white undersides, are frequently waved gracefully in the air. Their tail flukes, which are 4 m wide, are displayed prominently in the air before many of their dives. Sometimes the flukes are held stationary above the surface for a minute or more while the animal "head stands." The whales engage in intense "singing" in these waters day and night. The songs are easily heard underwater and at times even in the air.

Given this current great conspicuousness of the whales, and assuming that the whales were distributed historically as they are now, one would expect to find some acknowledgment of their presence by the Hawaiians of the precontact era before Captain Cook's 1778 discovery of the Islands. That this is not the case and that we additionally find no mention of the whales in writings of the early European and American visitors to the Islands until well into the nineteenth century suggests that the whales may be relatively recent immigrants to the waters they now inhabit around the main islands of Hawaii. The alternative hypothesis, that for the more than 1000 years of habitation of the Islands by the Hawaiians there was a pervasive total disinterest in the whales, could also explain the absence of indicators of their presence, but this would be at variance with what is known about developments in other Polynesian cultures where whales abound. It would also have to be assumed that the early foreign settlers in the several decades following contact with the Hawaiians were similarly disinterested in the whales. More detailed documentation relevant to these hypotheses is given below.

WHALES IN THE PRECONTACT PERIOD AND TO 1800?

A particularly good boat launching area and currently excellent shore vantage point for viewing the whales is the town of Lahaina and its environs on the island of Maui (Figure 2). Lahaina is a natural crossroads for any sea journey between Oahu and Hawaii and has a long history of habitation by the Hawaiians. From at least the eigh-

teenth century onward, it was the home of the royalty and was the first capital of the Hawaiian kingdom (Anonymous 1972). In 1799, estimates of the Islands' populations were made by the newly arrived Europeans. Maui, with from 40,000 to 75,000 inhabitants, was second in numbers only to the island of Hawaii (Schmitt 1968). Lahaina housed 4000 to 8000 inhabitants. Each winter, the residents of Lahaina should have had many opportunities to observe the whales disporting just offshore, were the whales distributed previously as they are today. Yet, examination of Hawaiian legends, myths, ceremonies, and rituals (Beckwith 1970, Fornander 1969, Kirtley 1971), their petroglyph drawings (Cox and Stasack 1970), the historical writings of early nineteenth-century Hawaiians (Malo 1951), and the Hawaiian language (Pukui and Elbert 1971), fails to yield evidence that humpback whales were known to pre-nineteenth-century Hawaiians living anywhere in the Islands.

There are no stories about whales in Hawaiian legends and myths, except for a very few that can be traced to origins among South Pacific Polynesian cultures (Beckwith 1970). There are no whale deities, though there are numerous shark gods and gods that take the form of various fish and marine invertebrates (Pukui and Elbert 1971). There are no ceremonies or rituals about whales, though one might expect that the periodicity of their annual migrations and their spectacular behavior would at least be incorporated as omens or signs within the highly developed, ritualized fishing enterprises of the pre-contact Hawaiians (Titcomb 1972). No whale is depicted within the approximate 135 identified petroglyph sites on the various islands, though other animal species such as birds, dogs, turtles, fish, crabs, pigs, and centipedes are occasionally portrayed (Cox and Stasack 1970). These sites include the elevated heights at Olowalu, Maui, approximately 5 nautical miles southeast of Lahaina, from which a commanding view of the entire Auau Channel area is obtained. The Auau Channel is currently a densely populated region for the breeding whales.

The Hawaiian language is exceptionally meager in words for whales or whale products, except for items dealing with whales' teeth (*palaoa*). Humpback whales are filter-feeding baleen (mysticete) whales, not toothed (odontocete) whales. Medium-sized toothed whales, such as pilot whales (*Globicephala macrorhynchus*) and false-killer whales (*Pseudorca crassidens*), with adult body length of perhaps 6 m (compared to 14 m for humpback whales), are common in offshore Hawaiian waters and occasionally beach or wash ashore. Such strandings historically could have provided a source of whale teeth for the Hawaiians. The pelagic nature of these whales indicates, however, that living specimens would have been rarely encountered by the Hawaiians. A number of species of dolphins of 2 to 3.7-m body length also inhabit Hawaiian waters (Tomich 1969), and they too occasionally beach or wash ashore. These fast-swimming animals were called *nai'a* by the Hawaiians, but the opportunities for their prolonged observation from shore or boat would have been rare. The large whale tooth found in some of the *lei niho palaoa* neck ornaments, an indicator of chiefly rank, is from the sperm whale. These teeth may have been obtained from the beaching of sperm whales which historically occasionally pass through Hawaiian waters in small numbers (Starbuck 1964, Townsend 1935), but it is more likely that the majority were brought to Hawaii from the Southern Hemisphere during the early transoceanic voyages of the Hawaiians. Whales' teeth were valued as ornaments throughout Polynesia (Cox 1967).

Other words in the Hawaiian language dealing with whale teeth include *palaoa ku'i*, a whale tooth pounder used for crushing medicine; *maku palaoa*, a fishhook made of ivory; *palaoa pae*, a whale tooth washed ashore; and *alelo*, the convex curve of the lower portion of the whale tooth necklace (Pukui and Elbert 1971). These examples demonstrate the nuances of language that can develop around an object or phenomenon that is visibly present in the culture or environment. Some language development of this type might be expected for the highly visible humpback whale and its products, were it present historically in Hawaiian waters. Products such as skeleton and baleen

plate could have been obtained from humpback whales washed ashore, such as the young calves who do not survive the birth trauma, even in the absence of any impetus to hunt the whales. There seem to be no baleen plate artifacts in the Hawaiian collection of the Bernice P. Bishop Museum in Honolulu. A few artifacts are labeled "whalebone," the whalers' term for baleen plate, but these seem to be of skeletal structure and not baleen plate. There is an understandable tendency for exhibitors to use the term "whalebone" mistakenly when meaning the bone of a whale. The bone of a whale could come from any of the toothed-whale species indigenous to Hawaiian waters.

There is a general word for whale in Hawaiian, *koholā*, possibly taken from the word for "reef" in apparent analogy to water rising in the air when striking a reef (Andrews 1865). The word is similar to the *tofua'a* and *tafora* of the Tongans and Tikopeans, respectively, and to the *tohorā* and *tafolā*, respectively, of the Tahitians and Samoans. A few Hawaiian whaling words exist, but these came into existence in the nineteenth century during the era of American whaling in the Pacific. These include *moku'o koholā* for whale ship (*moku* is of recent origin) and the English transliteration *koholā kepama* for sperm whale (Pukui and Elbert 1971).

The words *palaoa* and *koholā* are sometimes interpreted as referring to the sperm whale and humpback whale, respectively (Bryan 1915, Titcomb 1972), but this seems to be a modern conception based on current knowledge of these two species in Hawaiian waters and not their original usage. David Malo, a native Hawaiian who in 1839 completed his classic manuscript on Hawaiian history and culture (Malo 1951), noted that "*koholā* or whale was formerly called the *palaoa* [p. 47]."

SOME CONTRASTS WITH OTHER CULTURES OF OCEANIA

A number of the tropical islands of the South Pacific are known or believed to be winter assembly areas for humpback whales migrating northward from Antarctic feeding grounds. A population of humpback whales assembles each year in waters near Tonga, located at approximately the same latitude south of the equator (20°) as the main Hawaiian Islands are north of it. Smaller assemblies occur also near the Samoan and Fiji Islands, respectively, north and west of Tonga, and in the Tuamotuan Archipelago to the east, and probably at other islands as well. There have been very few anthropological studies of the relations of peoples of these oceanic islands to whales or other cetacea (for an exception, see Firth 1967). Despite this lack of direct study, it is not difficult to find evidence of awareness of the South Pacific Polynesians and other ethnic groups of the area of the existence of the whales. From these oceanic islands, particularly the Polynesian group, come a number of whale stories and legends. The whale is portrayed as a messenger; there are tales of tame whales, speaking whales, and helpful whales, including one who rescued infants; and there is a legend about the killing of the whales "Tonga" and "Samoa" and their subsequent resurrection (Beckwith 1970, Kirtley 1971, Stimson 1937). In the outlying Polynesian island of Tikopia in the Santa Cruz Islands group at 13° S latitude, there is a considerable body of language and ritual about whales (*tafora*). Here, the whale is seen as the embodiment of a spirit or deity (Firth 1967). The Tikopians also distinguished between sizes of whales by name —*tafora atu* was a whale that made a 9-m-long canoe seem small. There were special ceremonies connected with whales washed ashore and special words to denote aspects of the ceremony.

The Tongan peoples probably hunted whales before the nineteenth-century incursions of the American and European whaling vessels. Their continued subsistence taking of whales suggests a long heritage in whaling. The Tongan language contains many words about whales or whaling, though the recency of origin of the words is not always clear. Some words obviously predate the initial contact with foreign whalers, as they are similar to words in other Polynesian cultures, while other words clearly originated

in the postcontact period. In most cases, the words cannot be placed unambiguously into either time context. The general word for whales was *tofua'a*, which also means whale's flesh (Churchward 1959). The similarity to the words for whale in other Polynesian cultures is apparent. The whale's blow was *pupihi*. An area abounding in whales was *tofua'a'ia*. A whaling expedition was *folau hoka tofua'a*. *Kisu toto* or *puhi toto* or *pupuhi toto* meant the spouting of blood from a harpooned whale, and *toke* was to cut up or flense a whale. There were distinct words for humpback whales (*tofua'a hamupaka*) and sperm whales (*tofua'a sipamuelo*), though in each case the modifiers of *tofua'a* are recent English transliterations.

These illustrations serve to emphasize that in other tropical oceanic islands of the Pacific visited by humpback whales, evidence of native awareness of their presence can be found, even though, as noted, there has been very little anthropological effort devoted to the topic of whales in Oceania.

HUMPBACK WHALES IN HAWAII FROM 1800 TO 1870

The nineteenth century saw the rapid development of North Pacific whaling, primarily by American-owned whaling companies. The discovery in 1820 of rich sperm whale grounds near Japan soon brought hundreds of ships into the area eager to exploit the resource. Hawaii, centrally located between Japan and the American west coast, developed into a major staging area for ships on their way to and from the whaling grounds. Honolulu and Lahaina were the main ports or roadsteads for the ships, and whaling-related enterprises flourished at these sites. Also, from these locations many native Hawaiians were recruited to serve on the ships. The history of this era, comprising approximately the middle 50 years of the nineteenth century, is recorded in many sources (Kuykendall 1938, Starbuck 1964).

The first whaling ship to enter Hawaiian waters was the *Balaena* in 1818 (Purcell 1955). It anchored in Kealakekua Bay at the island of Hawaii and while there took a large sperm whale that yielded 102 barrels of oil. The sperm whales that occasionally occurred in Hawaiian waters were little exploited by the American whalers, who preferred to proceed to richer sperm whale grounds elsewhere in the North Pacific. Townsend's (1935) charts summarizing nineteenth-century whaling catches show only some 69 sperm whale catches in the close vicinity of the Hawaiian Islands, indicating their relative rarity in Hawaiian waters.

In the mid-nineteenth century, the first indications of the presence of the humpback whale in Hawaiian waters emerged in the form of reports of the establishment of shore whaling companies. Several enterprises on Maui in the 1840s attempted to take local whales, but the emphasis of these early companies was probably on the sperm whale rather than the humpback. Sperm oil sold for $1.00/gal in 1840, while whale oil rendered from blubber, such as from humpback whales, sold for only 30¢/gal (Morgan 1948). The sperm was the whale of choice economically until about 1860, though bowhead whaling in the Arctic Ocean, the Bering Sea, and other far northwest areas became of increasing interest after the mid-1840s. A 10-year permit issued in 1847 to James Hough to establish a shore station and to take whales in the area of Maui resulted in the taking of only one animal—a sperm whale that yielded 30 barrels of oil worth $800 (Anonymous 1848). The difficulty of finding the sperm whales and the expenses and efforts necessary to catch them seemingly closed down these early enterprises.

In the 1850s, additional shore stations were developed that emphasized the taking of humpbacks. In some cases, the whales are specifically identified by species; in other cases, the dates of operation of the stations coincided with the current periods of residency of the whales in Hawaii. On 2 March 1858, the Rev. Baldwin of Lahaina reported in a letter (Baldwin 1858) that "We have five whaling companies in and about Lahaina formed to take the whales from shore. Some of them consist entirely of natives." He states that "Today (March 2nd) was the first day that they met with any success." He goes on to describe the taking by natives

of a cow and calf, and bringing them 8 to 10 miles back to Lahaina. The next day the natives accepted the offer of Captain King of the ship *Sharon* to cut the whales and boil them in return for half the oil. This operation attracted hundreds of "foreigners and natives to watch the process," so apparently it was an unusual event locally.

In 1856, 2 years earlier, there is a description in *The Polynesian* of the taking of a cow and calf on 19 February by the first officer of the ship *Omega*, anchored off Lahaina (Anonymous 1856*b*). The officer noticed the "play of ten whales slowly swimming through the channel." He launched a whale boat, approached a mother, calf, and accompanying whale, and harpooned the mother. Wounded, she took off with the calf at a high rate of speed. The officer pursued them and to ensure capturing the mother, wounded and brought blood from the calf. The mother's care and protection was noted. The officer states that she swam round and round the wounded calf, apparently unmindful of her own wounds. She was attacked again and the "sight of thin blood and then thick blood told the story of success."

In that same year, 1856, Lahaina was being touted as a whaling ground in efforts to lure whaling ships away from the rival port of Honolulu. On 16 February 1856, the following letter appeared in *The Polynesian* (Anonymous 1856*a*): "Masters of whale ships lying in expense at Honolulu are earnestly requested to come to Lahaina, where they can not only recruit at a small expense and find there plenty of beef, vegetable ... but they can amuse their leisure hours in taking whales in our harbor, thereby adding to their wealth ...." The report also says, very optimistically, that "many whales may be seen in full view of our town, and Lahaina from its present appearances bids fair to rival the North West in its whale fisheries."

On 10 March 1859, there were reports from Lahaina that the shore whaling parties were doing well (Anonymous 1859): "Henry Turton's gang got one on Monday, a native party one yesterday and now Yankee party have just killed one in sight of town."

Sporadic reports of bay whaling continue through the 1860s. On 10 March 1866, a report in the *Pacific Commercial Advertiser* (Anonymous 1866) states that "whaling is occurring between Lahaina and Kalepolepo Bay which is a favorite winter resort of the humpback whales that go there to breed ...." It notes further that two shore stations were currently engaged in whaling. "The whales frequently appear in the Bay, but being generally wide awake the animals give the boats a wide berth."

These shore enterprises, at times numbering five or more, were begun close to the time when whale oil began declining rapidly in economic value, primarily because of the discovery of petroleum as an illuminant and lubricant in Pennsylvania and because of other world economic factors (Morgan 1948, Starbuck 1964). The economic decline apparently led to the demise of these establishments by the end of the 1860s. The last whaling report may be that of 1 May 1869 (Anonymous 1869), when a "Mr. Philip Milton fitted out a boat and during the forenoon ... fastened to the calf of a large humpback whale, which had been disporting opposite and about the landing (at Lahaina) for some hours." The calf dragged the whale boat between Lahaina and Lanai "all day." The cow remained close and was lanced several times. The calf was finally cut loose at about midnight when it headed for the deep water channel between Lanai and Kahoolawe. At that time, the cow was "spouting thin blood and was quite weak."

Aside from rare, desultory attempts to take a humpback whale or two, as recorded in local newspaper accounts (Anonymous 1856*b*), or as illustrated occasionally by artists (Fehrer 1969: 215), the nineteenth-century whale ships lying at anchor in the roadstead off Lahaina appeared to be disinterested in exploiting the seasonally resident stock. A sampling of log books available in Hawaii of whaling ships berthed at Lahaina during periods corresponding to the current winter assembly of the whales shows no records of captures in Hawaiian waters or even mention of the whales. (The log of *Omega* in Hawaiian waters was available only for dates after 20 October 1856, and the log of *Sharon* gave only its

South Pacific whaling voyage for the period 1845 to 1851. There are extensive log book collections elsewhere that should be reviewed to complete the picture of the whalers' account of the humpback whales in Hawaii.) Townsend's (1935) extensive data on locations where nineteenth-century whaling ships took whales show 137 humpback whale catches throughout the North Pacific, but none anywhere near Hawaii, the closest points being the Mariana Islands and the areas adjoining Baja California. This apparent lack of enterprise by the whalers visiting Maui again probably reflects the focus on the considerably more valuable sperm whale and the psychological difficulty of maintaining a working crew on board a vessel anchored just offshore of Lahaina, with its promises of gin and women.

In summary, the evidence reviewed reveals that humpback whales were present in noticeable numbers in waters they currently inhabit by the mid-nineteenth century. Shore whaling stations based on Maui began to exploit the whales at that time, and probably made moderate inroads into population numbers during their 15 to 25 years of operation. The increasing wariness of the whales and the general decline of world whaling industries during the latter third of the nineteenth century apparently prevented the decimation of the population. There is no evidence that the shore whaling parties, many of whom were native Hawaiians, had any prior experience with whales, as they seemed eager to rely on the instructions of the American whaling crews or masters whose ships were berthed in Lahaina. Coupled with the prior indications reviewed that the whales did not inhabit their present assembly areas during the pre-European era, one can estimate that their occupancy of this habitat might have developed extensively during the early postcontact period.

LATE NINETEENTH- AND TWENTIETH-CENTURY PRESENCE

The frequency of reported sightings of whales diminished by the turn of the century and continued at low levels through to the mid-1930s. Perhaps this indicated that with the departure of the whalers from Hawaii after the 1840s there was little interest in reporting the presence of whales. However, Bryan (1915) implied that humpback whales were less common near Maui in the early twentieth century than in previous times. It may be that the Lahaina shore whalers succeeded in driving a majority of the whales away from populated areas—at least for a number of generations. After the turn of the century, modern whaling got underway in the high-latitude regions of the North Pacific and probably made inroads into members of the Hawaiian population if they were feeding there along with other populations (the feeding areas for the Hawaiian population are not yet definitively known). Initially, the number taken was not large, but as was noted, the number increased considerably in the late 1920s and again in the early 1960s.

In the late 1930s and continuing through to the early 1950s, the appearance of the whales in Hawaiian waters began to be noted in newspaper reports from Oahu. The whales were apparently a novel sight at that time and attracted many viewers. As one example, on 24 March 1941, a pod of several whales milling near shore off Koko Head crater at the southeast tip of Oahu led to a huge traffic jam as cars stopped to watch the whales disport (Anonymous 1941).

Between 1941 and 1947, there is a gap in reported sightings in newspaper accounts, possibly reflecting the restrictions on activities of Hawaiian residents during World War II and the constraints placed on newspaper reports of any offshore events. However, it may also reflect a real absence of the whales during this period, possibly produced by the greatly increased sea activities in Hawaii during the war. On 14 January 1947, a newspaper report (Anonymous 1947) stated that "Capt. D. A. Hansen, pilot of the Matson Line planes in Honolulu ... reported (on January 11th) seeing a school of about 15 whales cavorting in the waters off Maui as the craft flew over that area .... These were the first whales reported seen

in Hawaiian waters in some time." In succeeding years, through the 1950s, the whales were so much more commonly seen that the Wailupe Whale Watchers' Association was formed. Wailupe is a peninsula on Oahu's south coast 3 nautical miles west of Koko Head crater. On 10 March 1953, a U.S. Fish & Wildlife Service research vessel reported large schools of humpback whales concentrated on the north of Oahu and on Penguin Bank (Anonymous 1953).

During the 1962 and 1963 seasons, over 3400 humpback whales were killed in their summer feeding grounds in the upper North Pacific, mostly by Russian whalers (International Whaling Statistics 1966). It was this large kill that led to a complete ban on the taking of humpback whales in the North Pacific, declared at the 1965 meeting of the International Whaling Commission. Very few whales were seen in the heavily populated Oahu areas during the latter part of the 1960s, judging by the rarity of newspaper accounts of the animals. Though the decline in sightings likely reflects the large northern kill, it might additionally indicate a local change in the distribution of the whales. Statehood for Hawaii in 1959 led to a building boom and to an ever-increasing influx of tourists, especially in the area from Koko Head crater to Pearl Harbor. The pile drivers and other construction noises, the runoff from bulldozed hills, and the tremendously increased boating and air traffic together could have driven the remaining whales from the area. They continue to be seen infrequently in this heavily populated area through to the present time, though they have reappeared abundantly elsewhere in the islands.

SUMMARY AND DISCUSSION

This historical review suggests that humpback whales first made their appearance in the Hawaiian habitat they now occupy less than 200 years ago. Seemingly, the whales were unknown to the Hawaiians of the pre-European era before 1778. We cannot definitely dismiss the alternative possibility that the Hawaiians simply paid no attention to the whales for more than 1000 years, but it seems to this writer as difficult to account for such a vagary in human behavior as to accept the possibility of a recent habitat change by the whales. Were archaeological digs to uncover ancient bone remnants of mysticete whales or baleen plate, the situation would change, but so far this has not been the case.

In the mid-nineteenth century the whales were present in significant enough numbers in the four-island region between the islands of Maui, Kahoolawe, Lanai, and Molokai to support shore whaling operations for some 15 to 25 years. The shore whaling operations in the Maui area may have dispersed much of the whale population. Few whales were seen in the four-island region or elsewhere near populated areas of Hawaii during the latter part of the nineteenth century through to the beginning of the third decade of the twentieth century, or else were seen and not reported (but see Bryan 1915).

Intensive exploitation of North Pacific humpback whales in their summer feeding grounds during the late 1920s and again in the early 1960s likely made large inroads into the Hawaiian population. However, the location of the feeding grounds of the Hawaiian population is still unidentified, so that we cannot be sure that significant numbers of the Hawaiian population were in fact represented among the thousands of humpback whales killed during those periods.

The increasing human population and the attendant construction boom on Oahu following 1959 statehood for Hawaii was associated with a retreat of the whales from waters adjoining the heavily populated and trafficked areas of Honolulu and environs. Few whales are seen in these areas today, and those that are observed appear to be transiting through the area rather than inhabiting it. There seems to have been a similar earlier retreat of the whales from populated areas near Oahu during World War II.

We can thus identify two human-related factors affecting occupancy of a habitat

by whales. One factor is direct whaling pressure in the habitat, which can lead to abandonment of an area by surviving whales. The nineteenth-century exploitation of the whales inhabiting the four-island region seems to have led to markedly reduced use of that region by survivors for possibly as long as 60 years. This effect of whaling on the survivors is consistent with what is known for some other exploited populations, such as the retreat of humpback whales from nearshore areas of intensive whaling in South Georgia in the Antarctic to waters further offshore (Ommaney 1971). Harmer (1929) and Kellogg (1929) discussed the abandonment of other areas of habitation by whales in response to whaling activities.

The second factor affecting occupancy is nonlethal disturbance occasioned by increased marine and air traffic, onshore construction activities, increased runoff and pollution, and possibly a general rise in undersea ambient noise levels. The decline in whale sightings in the Honolulu nearshore areas during World War II and then again after 1960 may partially reflect this factor. It is not uncommon to find cetaceans relocating when disturbed. Populations of cetaceans along the densely populated northeast coast of the United States have retreated from many areas of their former habitation, some of which were breeding grounds (see description of work of J. Mead in Lampe 1975). A recent report by Nishiwaki and Sasao (1977) provides evidence that species of both toothed and baleen whales have retreated from areas of heavy maritime use in waters near Japan. According to Bartholomew (1974), San Diego Bay in California was a former breeding ground for gray whales (*Eschrichtius gibbosus*), but its use was preempted by human activities there. Our aerial surveys of the whales in Hawaii over the last 2 years have revealed that the density of concentration of humpbacks tends to be inversely related to the density of the concentration of the human population on shore or human-related offshore marine activities. It seems possible that the currently increasing levels of human-generated disturbances in offshore areas near Maui could result in a retreat of the whales from portions of that region.

A final question is whether there are any mechanisms that could account for the relocation of the whales to their present Hawaiian habitat some 200 years ago, as has been surmised. Though any postulated mechanism would have an ad hoc quality, its generality can be evaluated against known data from other cases where available. The first possible mechanism concerns the effects of natural and induced dispersion of individuals. Some whales in a population likely meander naturally during their annual migration, like the occasional humpback whale sighted in the Northwest Hawaiian Islands. Other individuals might be induced to disperse through whaling pressures elsewhere, such as the continual low-level exploitation in Japanese waters from the early seventeenth century onward (Omura et al. 1953). We would expect the incidence of whaling to increase the rate of dispersal of individuals. However, the central tropical North Pacific, unlike corresponding regions of the South Pacific, is nearly devoid of landmasses and shallow banks, which are important breeding habitat requirements for humpback whales (Dawbin 1966, Winn 1977). The Hawaiian Islands are a rare event in an otherwise nearly land-barren central tropical region. This rarity factor alone could have delayed uncovering of the Hawaiian habitat by dispersed whales until relatively recent times. Through the increased dispersal rate resulting from whaling pressure, some dispersed individuals may finally have come upon the Hawaiian chain several hundred years ago, returned to it in successive years, and gradually enlisted other whales in the new migration until a significant and conspicuous self-sustaining breeding population emerged. Enlistment of conspecifics might take place through the continuation of associations developed in summer feeding grounds (Nemoto 1964) or through other species-typical aggregating behaviors. Prolonged, powerful vocalizations characterize humpback whale behavior during the breeding season. It has been hypothesized that these sounds, especially their low-frequency com-

ponents, may carry for great distances in the ocean under favorable acoustic conditions (Payne and Webb 1971). If this is the case, whales occupying a suitable breeding habitat, or perhaps enroute to it, could enlist conspecifics attracted to the calls if the receivers are able to follow an acoustic intensity gradient or other acoustic cue to the emitters.

A second possible mechanism involves changes in the oceanographic characteristics of habitats. A surface water temperature of approximately 25°C is another important breeding habitat requirement for the whales (Dawbin 1966, Winn 1977). The surface temperature in a given region at a given season can be modified on a long-term basis by changes in the locations of watermasses. It was noted that three large North Pacific watermasses converge near the Hawaiian Islands (Sverdrup et al. 1942), and it might be supposed that a long-term displacement of these masses near the beginning of the nineteenth century altered the temperature of the current Hawaiian habitat of the whales, making it suitable for their use. Short-term changes in watermasses have been recorded in recent times, giving some weight to the possibility of more permanent or longer-term cyclical changes (La Fond 1962). For example, in 1939 the Equatorial watermass reached northward all the way to the Hawaiian Islands (Sverdrup et al. 1942). In 1955, the North Pacific Central watermass was displaced northward, and in 1957, it was displaced southward (Seckel 1962).

To detect changes in surface water temperature in the Hawaiian Island region, it must be assumed that the population of whales was already concentrated somewhere close to the main Hawaiian Islands and that as the temperature changed the whales tracked the preferred values to the main islands. The Northwest Hawaiian Island chain lies closer to the high-latitude summer feeding areas of humpback whales in the Aleutian Islands region than do the main islands of Hawaii (Figure 1) and might have been used as a major assembly area during a time when the winter surface water temperatures there were warmer than now. This could have been the case if the Equatorial watermass lay further north than now. A retreat of that watermass southward in more recent times would then bring the whales with it. That cetaceans are sufficiently sensitive to changes in the physical parameters of a habitat to detect suboptimal conditions and shift to other areas is supported by observations of changes in distributions of toothed cetaceans with short-term changes in local watermasses, currents, and locations of upwellings (S. Leatherwood, personal communication). Though in most cases these changes are associated with the redistribution of food resources, there seems little reason to doubt that reproductive factors could also provide strong incentives for relocation of a habitat.

In conclusion, the record reviewed and the hypotheses advanced suggest that *Megaptera* is sensitive to changes in physical and psychological variables in its breeding habitat and seems able to make suitable adaptive responses to such changes through habitat shift and local site alterations. Given the low annual reproductive rate of *Megaptera* (and other large whales), the 6 to 10 years of growth until sexual maturity, and its extended sexual and physical longevity (Mackintosh 1972), one might expect selection for considerable flexibility in an individual's response during its lifetime to changes in habitat conditions that might affect reproductive fitness.

ACKNOWLEDGMENT

I wish to thank Paul Forestell for helpful comments on the manuscript.

LITERATURE CITED

ANDREWS, L. 1865. A dictionary of the Hawaiian language. H. M. Whitney, Honolulu. 599 pp.

ANONYMOUS. 1848. The whale fishery. The Polynesian, 20 May. p. 3.

ANONYMOUS. 1856*a*. Letter to the editor. The Polynesian, 16 Feb. p. 162.

ANONYMOUS. 1856*b*. Letter to the editor. The Polynesian, 23 Feb. p. 166.

ANONYMOUS. 1859. Untitled article. The Polynesian, 10 Mar. p. 186.

ANONYMOUS. 1866. Bay whaling. Pacific Commercial Advertiser, 10 Mar. p. 2.

ANONYMOUS. 1869. Untitled article. Pacific Commercial Advertiser, 1 May. p. 3.

ANONYMOUS. 1941. Untitled article. Honolulu Advertiser, 24 Mar. p. 1.

ANONYMOUS. 1947. Untitled article. Honolulu Advertiser, 14 Jan. p. 5.

ANONYMOUS. 1953. Untitled article. Honolulu Star-Bulletin, Honolulu, 10 Mar. p. 1.

ANONYMOUS. 1972. Story of Lahaina. The Lahaina Restoration Foundation, Lahaina, Maui.

BALDWIN, D. 1858. Letter 2 Mar. 1858. Journal of the Rev. D. Baldwin 1848–1858. Vol. 3. Hawaii Mission Children's Society, Honolulu.

BARTHOLOMEW, G. A. 1974. The relation of the natural history of the whales to their management. Pages 294–302 *in* W. E. Schevill, ed. The whale problem: A status report. Harvard University Press, Cambridge, Mass.

BECKWITH, M. 1970. Hawaiian mythology. University Press of Hawaii, Honolulu. 575 pp.

BRYAN, W. A. 1915. Natural history of Hawaii. Hawaiian Gazette, Honolulu. 596 pp.

CHAPMAN, D. G. 1974. Status of Antarctic rorqual stocks. Pages 218–238 *in* W. E. Schevill, ed. The whale problem: A status report. Harvard University Press, Cambridge, Mass.

CHURCHWARD, C. M. 1959. Tongan dictionary. Oxford, London. 836 pp.

COX, J. H. 1967. The lei niho palaoa. Pages 411–424 *in* G. A. Highland, R. W. Force, A. Howard, M. Kelly, and Y. H. Sinoto, eds. Polynesian cultural history. Bishop Museum Press, Honolulu.

COX, J. H., and E. STASACK. 1970. Hawaiian petroglyphs. Bishop Museum Press, Honolulu. 100 pp.

DAWBIN, W. H. 1966. The seasonal migratory cycle of humpback whales. Pages 145–170 *in* K. S. Norris, ed. Whales, dolphins, and porpoises. University of California Press, Berkeley, Ca.

FEHRER, J. 1969. Hawaii: A pictorial history. Bishop Museum Press, Honolulu.

FIRTH, R. 1967. Sea creatures and spirits in Tikopia belief. Pages 539–564 *in* G. A. Highland, R. W. Force, A. Howard, M. Kelly, and Y. H. Sinoto, eds. Polynesian cultural history. Bishop Museum Press, Honolulu.

FORNANDER, A. 1969. An account of the Polynesian race: Its origins and migrations. Vol. 3. Chas. E. Tuttle, Rutland, Vt. 292 pp.

HARMER, S. F. 1929. The history of whaling. Norsk Hvalfangst-Tidende 2:35–45.

HERMAN, L. M., and R. ANTINOJA. 1977. Humpback whales in the Hawaiian breeding waters: Population and pod characteristics. Sci. Rep. Whales Res. Inst. Tokyo 29:59–85.

INTERNATIONAL WHALING STATISTICS XVI. 1942. Committee for Whaling Statistics, Oslo.

INTERNATIONAL WHALING STATISTICS LVII. 1966. Committee for Whaling Statistics, Oslo.

KELLOGG, R. 1929. Address before the American Society of Mammalogists. Ann Arbor, Mich. 9 April.

KING, J. E., and J. DEMOND. 1953. Zooplankton abundance in the central Pacific. U.S. Fish Wildl. Serv. Fish. Bull. 82:111–143.

KING, J. E., and T. S. HIDA. 1954. Variations in zooplankton abundance in Hawaiian waters, 1950–52. U.S. Fish Wildl. Serv. Spec. Sci. Rep.: Fisheries 118:1–54.

KIRTLEY, B. F. 1971. A motif-index of traditional Polynesian narratives. University Press of Hawaii, Honolulu. 486 pp.

KUYKENDALL, R. S. 1938. The Hawaiian kingdom 1778–1854. Vol. 2. Foundations and transformations. University Press of Hawaii, Honolulu. 453 pp.

LA FOND, E. C. 1962. Temperature structure of the upper layer of the sea and its variation with time. Pages 751–767 *in* F. G. Brickwedde, ed. Temperature: Its measurement and control in science and industry. Vol. 3, pt. 1. Reinhold, New York.

LAMPE, D. 1975. The whale chaser. Nat. Wildl. 13:24–26.

MACKINTOSH, N. A. 1972. Biology of the populations of large whales. Sci. Prog. Oxf. 60:449–464.

MALO, D. 1951. Hawaiian antiquities. Bernice P. Bishop Mus. Spec. Publ. 2. 278 pp.

MORGAN, R. 1948. Hawaii: A century of economic change 1778–1876. Harvard University Press, Cambridge, Mass. 260 pp.

MYERS, N. 1975. The whaling controversy. Amer. Sci. 63:448–455.

NEMOTO, T. 1964. Schools of baleen whales in the feeding areas. Sci. Rep. Whales Res. Inst. Tokyo 18:89–110.

NISHIWAKI, M., and M. SASAO. 1977. Human activities disturbing migration routes of whales. Sci. Rep. Whales Res. Inst. Tokyo 29:113–120.

OMMANEY, F. D. 1971. Lost leviathan. Dodd, Mead, New York. 280 pp.

OMURA, H., K. MAEDA, and I. MIYAZAKI. 1953. Whaling in the adjacent waters of Japan. Norsk Hvalfangst-Tidende 42: 199–212.

PAYNE, R., and D. WEBB. 1971. Orientation by means of long range acoustic signalling in baleen whales. Ann. N.Y. Acad. Sci. 188:110–141.

PUKUI, M. K., and S. H. ELBERT. 1971. Hawaiian dictionary. University Press of Hawaii, Honolulu. 590 pp.

PURCELL, H. G. 1955. Hawaii and the whaling fleet. Naut. Res. J. 7:3–6.

RICE, D. W. 1977. The humpback whale in the North Pacific: Distribution, exploitation, and numbers. Paper presented at the Workshop on Humpback Whales in Hawaii. Honolulu, 6–8 July.

SCAMMON, C. M. 1968. The marine mammals of the northwestern coast of North America. Dover, New York. 319 pp.

SCHMITT, R. C. 1968. Demographic statistics of Hawaii: 1778–1965. University Press of Hawaii, Honolulu. 271 pp.

SECKEL, G. R. 1962. Atlas of the oceanographic climate of the Hawaiian Islands region. U.S. Fish Wildl. Serv. Fish. Bull. 193:321–427.

SHALLENBERGER, E. W. 1976. Report to Seaflite and Sea Grant on the population of humpback whales in Hawaii. Mimeographed. Sea Grant office, University of Hawaii, Honolulu.

STARBUCK, A. 1964. History of the American whale fishery from its earliest inception to the year 1876. Vol. 1. Argosy-Antiquarian, New York. 799 pp.

STIMSON, F. J. 1937. Tuamotuan legends (Islands of Anna). Bernice P. Bishop Mus. Bull. 148. 147 pp.

SVERDRUP, H. U., M. W. JOHNSON, and R. H. FLEMING. 1942. The oceans: Their physics, chemistry, and general biology. Prentice-Hall, Englewood Cliffs, N.J. 1060 pp.

TITCOMB, M. 1972. Native use of fish in Hawaii. University Press of Hawaii, Honolulu. 175 pp.

TOMICH, P. Q. 1969. Mammals in Hawaii. Bishop Museum Press, Honolulu. 238 pp.

TOWNSEND, C. H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. Zoologica 19:3–50.

WINN, H. E. 1977. Environmental correlates of the humpback whale on the tropical winter calving grounds. Paper presented at the Workshop on Humpback Whales in Hawaii. Honolulu, 6–8 July.

WOLMAN, A. A., and C. M. JURASZ. 1977. Humpback whales in Hawaii: Vessel census 1976. Mar. Fish. Rev. 39:1–5.